# ADVANCES IN TELEMEDICINE USING MOBILE COMMUNICATIONS

R. S. H. Istepanian[1], B. Woodward[2] and C. I. Richards[2]
[1]Department of Electronic and Computer Engineering, Brunel University
Uxbridge, Middlesex, UB8 3PH, England
[2]Department of Electronic and Electrical Engineering, Loughborough University
Leicestershire, LE11 3TU, England

*Abstract* – **Future telemedicine systems will exploit mobile communications technology so that patients who are free to move around at home or at work, or in emergency medical situations, can be monitored in a hospital. At present, the GSM mobile telephone cellular network is limited to 9.6 kbps, but with the introduction of the third generation (3G) network, data rates of 144 kbps will be available, giving scope for the transmission of much more biomedical data as well as voice and video data if required. The paper discusses some of the issues involved and outlines the types of systems that will be viable with the new technology.**
***Keywords* – Telemedicine, communications**

## I. INTRODUCTION

The aim of telemedicine is to improve the quality of health care and reduce its costs by faster communication of medical information between physicians and patients. A principal advantage of telemedicine, and a significant innovation in the way medical care is delivered, is that the doctor and patient need not be in the same place or even in the same country. Telemedicine is seen as a potentially powerful means of improving the quality of health monitoring and promises to offer a cost-saving alternative to some of the current forms of health care delivery. Considerable research on telemedicine has been conducted in the UK, USA and other countries, mainly using "landlines" such as the Public Switched Telephone Network (PSTN). Recently there has been interest in the potential use of small *mobile* units for transmitting biomedical data via telecommunications cellular networks for emergency or home care applications [1,2]. Such systems are overdue for serious consideration, especially in view of the current evolution of Third Generation (3G) mobile systems and the proliferation of interest and applications in mobile data communications systems.

This paper focuses on the design and development of a modular mobile integrated telemedicine system using a conventional mobile telephone. The system is capable of transmitting an electrocardiogram (ECG) from a patient via the GSM cellular network to some remote receiving point. This allows the transmission of medical data from sensors, attached to patients at home or during normal day-to-day activities or in emergency situations, to a hospital or medical centre. To implement such a system is a challenging and innovative aim that is the fulfilment of a real need in society. This is based on the realistic assumption that telemedicine will have to adapt to the anticipated global development of personal mobile telecommunications in the next few years. Any system therefore needs to be "future-proofed" in view of constantly evolving telecommunications technology and with special regard to the advent of the 3G protocol as a replacement for the present GSM protocol.

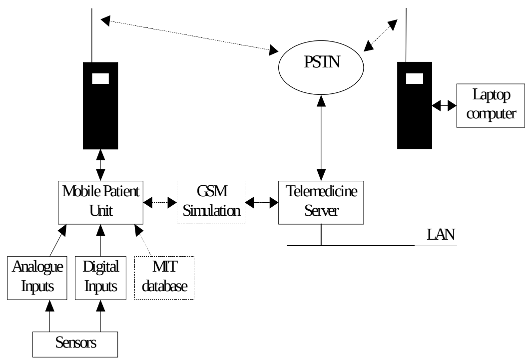


Fig. 1 Telemedicine system with mobile telephone and PSTN communications links

## II. METHODOLOGY

Applications of telemedicine suitable for use with cellular networks include the real-time transmission of medical data to hospitals from medical devices attached to patients at home or at work. A system that has been designed for this

# Report Documentation Page

| Report Date | Report Type | Dates Covered (from... to) |
|---|---|---|
| 25 Oct 2001 | N/A | - |

| | |
|---|---|
| **Title and Subtitle**<br>Advances in Telemedicine Using Mobile Communications | **Contract Number** |
| | **Grant Number** |
| | **Program Element Number** |
| **Author(s)** | **Project Number** |
| | **Task Number** |
| | **Work Unit Number** |
| **Performing Organization Name(s) and Address(es)**<br>Department of Electronic and Computer Engineering Brunel University Uxbridge, Middlesex, UB8 3PH England | **Performing Organization Report Number** |
| **Sponsoring/Monitoring Agency Name(s) and Address(es)**<br>US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500 | **Sponsor/Monitor's Acronym(s)** |
| | **Sponsor/Monitor's Report Number(s)** |

**Distribution/Availability Statement**
Approved for public release, distribution unlimited

**Supplementary Notes**
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

**Abstract**

**Subject Terms**

| | |
|---|---|
| **Report Classification**<br>unclassified | **Classification of this page**<br>unclassified |
| **Classification of Abstract**<br>unclassified | **Limitation of Abstract**<br>UU |

**Number of Pages**
3

purpose is shown in Fig. 1. The mobile patient unit is designed as a waist-mounted holster that provides a cradle for the mobile telephone to be placed in whilst the system is in use. When the system is not in use the telephone can be used for standard voice calls. The main criterion is that the telephone needs to have an industry-standard infra-red protocol. Ericsson provided full documentation for their modern command set, so an Ericsson SH-888 was used for the prototype. Fig. 1 also shows how the mobile unit connects to the rest of the system via PSTN and via the server to the local area network (LAN) inside a hospital. For the purposes of running simulations and system tests against known data, recordings from the MIT arrhythmia database were used [3].

The patient mobile unit is based around an embedded computer running a proprietary operating system primarily designed to support the real-time acquisition of data from the patient, and to support the interface to the mobile telephone. Additional interfacing is necessary to provide analogue inputs from ECG sensors, to provide infra-red interfaces for the telephone, and to provide the patient with status messages. The various layers of the infra-red (IrDA) protocol stack (not shown here) are publicly documented [4]. One additional hardware layer of “IR multiplex” has been added to allow multiple infra-red interfaces to be built into the device, permitting the use of different brands of mobile telephone having the infra-red interface in different locations.

For the system outlined here it is fundamental that the data transmitted to the hospital are archived and made available to consultants as and when required, therefore a hospital-based server was also developed. The incoming data from the patient includes the International Mobile Subscriber Identity (IMSI) number, which is unique to the Subscriber Identity Module (SIM) card present in the mobile telephone. This number is used to identify the patient to the system and to permit the storing of additional records for that patient.

Once the consultant has identified to the database, a full list of recordings for a given patient are displayed and individual ECG traces can be examined from the consultant’s own office using the internal LAN.

There would normally be no requirement for the hospital to have an exact replica of the data recorded by the patient’s unit, provided the data are only used to monitor a patient and not to provide a clinical diagnosis, which would almost certainly need to be made in a face-to-face consultation. The benefits from compressing the data as much as possible are particularly relevant when the connection is via the slow and expensive GSM link in this system. Various approaches to compression of ECG signals were considered, starting with existing time-domain techniques such as TP, AZTEC, CORTES, FAN (and variants SAPA, SAPA-2) [5], which were suitable for a peak compression ratio of about 10:1, and developing approaches based on wavelets, which were suitable for ratios of about 18:1 whilst still providing clinically acceptable results [6] ,[7].

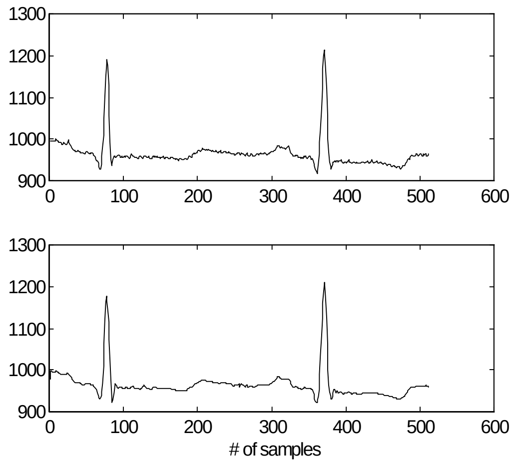


Fig. 2 Transmitted and received ECG samples (normalised amplitudes) using MIT-BIH Arrhythmia database [3].

.

## III. RESULTS

Fig. 2 shows a sample ECG trace displayed through an internal LAN. To facilitate comparison with original data, this is a record from the MIT database rather than an actual recording from a patient. The data were transferred from the Flash ROM of a (stationary) mobile patient unit through the GSM network and into the server. No transmission errors have yet been observed, although it is anticipated that the error performance will be degraded if the patient unit is truly mobile. Mobile tests are planned but have not been carried out due to the time-scales involved in reducing the size of the electronics to a portable form. It may, therefore, be necessary to introduce acknowledgment message from the server to the mobile unit to indicate successful receipt of a packet or a demand for re-transmission.

## IV. DISCUSSION

Telemedicine is a potentially powerful means of improving the quality of health monitoring and promises to offer a cost-saving alternative to

some of the current forms of health care delivery. Any potential cost savings cannot be reliably established at present but are a major incentive to pursuing telemedicine as an important research activity. High-speed communications are essential for developments in telemedicine for the transfer of data. At present, GSM is widely used as the global system for mobile communications, a digital system whose architecture is based on Integrated Services Data Network (ISDN). Whereas ISDN operates with a basic rate of 64 kbit/s, GSM has a full channel rate of only 22.8 kbit/s, which includes significant coding. The coding has proved to be a useful feature in the work described here because although the actual data rate is limited to only 9.6 kbit/s, the probability of error transmissions is drastically reduced. It is recognised that GSM will eventually be replaced in due course by 3G, which will have a much greater data rate capability (144 kbit/s), comparable with that for the *Bluetooth* technology (434 kbit/s) that is also likely to be used for short-range telemedicine applications. This will allow much more data to be transmitted and will be particularly suited to the transmission of several channels of bio-medical data.

## V. CONCLUSIONS

The main contribution of this paper is to describe the present scope and future potential of mobile communications in telemedicine. A modular structured GSM-based mobile telecardiology system is used to illustrate the concept. The system carried by the patient comprises a mobile telephone linked to a processing unit by an infra-red channel. The telephone/processor unit accepts signals from one or more sets of sensors attached to the patient. The prototype version is designed to transmit digitised electrocardiogram signals to a hospital via the GSM mobile telephone cellular network. New compression and signal processing algorithms, such as wavelet techniques, can be integrated to optimise the performance of the system under different mobile conditions. A further development is the encryption and subsequent decryption of the signals to ensure medical confidentiality. The modular design of the system should enable telemedicine providers to adapt to future mobile 3G standards.

## REFERENCES


[1] S. Pavlopoulos, E. Kyriacou, A. Berler, S. Dembeyiotis, and D. Koutsouris, “A novel emergency telemedicine mobile system - AMBULANCE,” *IEEE Trans. Information Technol. in Biomedicine*, Vol 2, pp. *-*, 1998.

[2] B. Woodward, R. S. H. Istepanian, and C. I. Richards, “Design of a telemedicine system using a mobile telephone,” *IEEE Trans. Information Technol. in Biomedicine*, vol. 5, pp. 13-15, March 2001.

[3] MIT-BIH Arrhythmia Database, information online at http:/ecg.mit.edu.

[4] Infra-red protocol information online at http:/www.irda.org.

[5] W. J. Tompkins (Ed), *Biomedical Digital Signal Processing.* London, U.K.: Prentice Hall, 1993.

[6] E. Econompoulos, L. Hadjileontadis, R. S. H. Istepanian, and S. Panas, “Robust ECG coding using wavelet analysis and higher order statistics,” in Colloquium Digest on *Intelligent Methods in Health Care and Medical Applications*, IEE Publication 98/514, York, U.K., Oct. 20, 1998, pp. 15/1-15/6.

[7] R. S. H. Istepanian and A. Petrossian, “Optimal wavelet-based ECG data compression for mobile telecardiology system,” *IEEE Trans. Information Technol. in Biomedicine*, vol. 4, pp. 200-211, Sept. 2000.